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August 23, 2002  
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APPLICATION FOR LETTERS PATENT

**SEMICONDUCTOR COMPONENT WITH ON  
BOARD CAPACITOR AND METHOD OF  
FABRICATION**

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ATTORNEY'S DOCKET NO. 02-0083

Field of the Invention

This invention relates generally to semiconductor manufacture and packaging. More particularly, this invention 5 relates to a semiconductor component having an on board capacitor, to a method for fabricating the component, and to systems incorporating the component.

Background of the Invention

10 One type of semiconductor package includes several semiconductor components in a single package module. The semiconductor components can be in the form of semiconductor dice, semiconductor packages, or semiconductor wafers. This type of package is sometimes referred to as a multi chip 15 module (MCM) package, or as a system in a package (SIP).

Typically, the MCM package is constructed to provide a system level of functionality, such as a control or memory function. As such, the MCM package can include different types of semiconductor components configured to perform 20 different functions in the system. For example, a MCM package configured as a micro controller can include a microprocessor component, and one or more memory components, such as SRAMs, DRAMs, or flash memories.

MCM packages offer increased system performance, because 25 the integrated circuits on the semiconductor components can be operated more efficiently. This is largely a result of decreasing the interconnection length between the components. In addition, system performance is improved because the input/output ports for the MCM package can be configured to 30 access the whole system, which can be organized to reduce signal delays and access times. The power requirements are also reduced due to a reduction in the driver requirements.

One problem that occurs in the MCM packages results from parasitic inductance. For example, parasitic inductance can

result from switching transients and cross coupling between the conductors (e.g., wires or traces) that electrically connect the different components in the MCM package. Parasitic inductance can cause transient voltages, spurious 5 signals, and power supply noise, which degrade the operation of the semiconductor components, and adversely affect the performance of the system. Parasitic inductance can also make testing of the MCM packages more difficult because false 10 readings are obtained, making electrical evaluation of the packages more difficult. Parasitic inductance is particularly a problem at clocking speeds of 500 mHz or more.

One technique for overcoming parasitic inductance is by filtering the transient voltages, spurious signals and power supply noise. For example, external de coupling capacitors 15 can be surface mounted within the MCM packages or on a substrate, such as a circuit board or test board, containing the MCM packages. One problem with these external capacitors is that they are susceptible to shorting, and also to mechanical damage due to their surface mounting. In 20 addition, the conductive paths between the capacitors and the components, or the integrated circuits on the components, can also produce parasitic inductance. As MCM packages, and other systems containing multiple semiconductor components, become more densely populated with components, problems 25 associated with parasitic inductance are increased.

The present invention reduces the problems associated with parasitic inductance by incorporating an on board capacitor into the structure of a component. In addition, the on board capacitor is more durable than conventional 30 surface mount capacitors, is protected by the structure of the component, and is closer to the integrated circuits contained on the component. The present invention is also directed to a novel method for fabricating components with on

board capacitors, and to improved systems incorporating the components.

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### Summary of the Invention

In accordance with the present invention, a semiconductor component, a method for fabricating the component, and systems incorporating the component are provided. In an illustrative embodiment, the component comprises a semiconductor package containing a single die. The die includes integrated circuits, and die contacts, such as bond pads, in electrical communication with the integrated circuits.

In addition to the die, the component includes an array terminal contacts, and an on board capacitor in electrical communication with selected terminal contacts and selected die contacts. The capacitor is configured to filter transient voltages, spurious signals, and power supply noise resulting from parasitic inductance. The capacitor includes a first electrode and a second electrode separated by a dielectric layer. In the illustrative embodiment, the first electrode is in electrical communication with a ground (Vss) die contact, and with a ground (Vss) terminal contact. The second electrode is in electrical communication with a power (Vcc) die contact, and with a power (Vcc) terminal contact.

The fabrication method is preferably performed on a wafer containing multiple semiconductor dice which are made into the components, and then singulated into the separate components. The fabrication method includes the steps of forming the first electrodes on the dice using a first metal layer in contact with the ground (Vss) die contacts, forming a dielectric layer on the first electrodes, and then forming second electrodes on the dice using a second metal layer in

contact with the power (Vcc) die contacts. The first metal layer can comprise a portion of a first redistribution layer (RDL1) formed on an electrically insulating layer such as a passivation layer. The dielectric layer can comprise a 5 deposited and cured polymer, and the second metal layer can comprise a portion of a second redistribution layer (RDL2).

The component can be used to construct systems such as MCM packages, and multi chip modules. In an alternate embodiment a wafer component comprises a semiconductor wafer 10 containing multiple dice, with each die having an on board capacitor. The wafer component can be used to construct systems such as circuit boards and modules.

Brief Description of the Drawings

15 Figure 1A is a plan view of a semiconductor component constructed in accordance with the invention;

Figure 1B is a side elevation view of Figure 1A;

Figure 1C is an enlarged, partially cut away portion of Figure 1A;

20 Figure 1D is an enlarged schematic cross sectional view taken along section line 1D-1D of Figure 1C;

Figure 1E is an enlarged schematic cross sectional view taken along section line 1E-1E of Figure 1C;

25 Figure 2 is a schematic cross sectional view of a packaged system incorporating components constructed in accordance with the invention;

Figure 3A is a plan view of a semiconductor multi chip module incorporating components constructed in accordance with the invention;

30 Figure 3B is a schematic cross sectional view taken along section line 3B-3B of Figure 3A;

Figure 3C is an enlarged schematic cross sectional view taken along section line 3C-3C of Figure 3B;

Figures 4A-4F are schematic cross sectional views illustrating steps in a method for fabricating the semiconductor component of Figures 1A-1E;

Figure 5A is view taken along line 5A-5A of Figure 4A;

5 Figure 5B is a cross sectional view taken along line 5B-5B of Figure 4B;

Figure 5C is a cross sectional view taken along line 5C-5C of Figure 4C;

10 Figure 5D is a cross sectional view taken along line 5D-5D of Figure 4D;

Figure 5E is a cross sectional view taken along line 5E-5E of Figure 4E;

15 Figure 5F is a cross sectional view taken along line 5F-5F of Figure 4F;

Figure 6A is a schematic plan view of an alternate embodiment wafer component constructed in accordance with the invention;

Figure 6B is a cross section taken along line 6B-6B of Figure 6A illustrating a die on the wafer component; and

20 Figure 6C is a schematic cross sectional view of an electronic assembly constructed with the wafer component.

#### Detailed Description of the Preferred Embodiments

As used herein, the term "semiconductor component" 25 refers to an electronic element that includes a semiconductor die. Exemplary semiconductor components include semiconductor dice, semiconductor packages, semiconductor wafers, BGA devices, multi chip modules and circuit boards.

Referring to Figures 1A-1E, a semiconductor component 30 10P constructed in accordance with the invention is illustrated. In this embodiment, the component 10P comprises a semiconductor package, such as a chip scale package (CSP).

The component 10P includes a semiconductor die 12, and a plurality of terminal contacts 14. The die 12 can comprise a

conventional semiconductor die having a desired electrical configuration. For example, the die 12 can be a memory device, such as a DRAM, SRAM or flash memory. In the illustrative embodiment, the component 10P and the die 12 are 5 generally rectangular in shape, but other shapes such as square can be utilized. In addition, the component 10P and the die 12 are substantially the same size, and have matching peripheral outlines.

The die 12 includes a pattern of die contacts 16, such 10 as bond pads embedded within an electrically insulating passivation layer 18 (Figure 1D). The die contacts 16 and the die passivation layer 18 are located on a face 21 (circuit side) of the die 12, with the die contacts 16 located below the surface of the passivation layer 18. In 15 the illustrative embodiment the die contacts 16 are located along a center line 20 of the die 12, which is also the center line of the component 10P. As shown in Figures 1D and 1E, the die 12 also includes internal conductors 22 in electrical communication with the die contacts 16 and with 20 integrated circuits 24 contained on the die 12.

The component 10P also includes an outer protective layer 28. As shown in Figures 1D and 1E, the terminal contacts 14 are located in openings 26 formed through the outer protective layer 28. The outer protective layer 28 can 25 comprise a dielectric material adapted to electrically insulate and protect the component 10P.

The terminal contacts 14 can comprise solder bumps, or balls, bonded to under bump metallization layers 30. The terminal contacts 14 provide electrical connection points 30 from the outside world to the integrated circuits 24 and other electrical devices on the component 10P. In the illustrative embodiment, the terminal contacts 14 are arranged in a ball grid array composed of six rows and sixteen columns. However, as is apparent, other dense area

arrays, or patterning arrangements, can be used for locating the terminal contacts 14. The terminal contacts 14 permit the component 10P to be flip chip mounted circuit side down to mating electrodes on a supporting substrate, such as a 5 circuit board. Accordingly the component 10P can be referred to as a "flip chip" component.

The component 10P also includes an on board capacitor 32 configured to filter transient voltages and spurious signals, such as those produced by parasitic inductance, and to reduce 10 power supply noise. The capacitor 32 thus improves the performance of the component 10P and improves test procedures, such as burn-in conducted on the component 10P. The capacitor 32 is in electrical communication with a ground terminal contact 14Vss, and in electrical communication with 15 a power terminal contact 14Vcc for the component 10P.

As shown in Figures 1D and 1E, the capacitor 32 includes a first (lower) electrode 34 and a second (upper) electrode 36 separated by a dielectric layer 38. The first (lower) electrode 34 is in electrical communication with the ground 20 terminal contact 14Vss and with a ground die contact 16Vss. The second (upper) electrode 36 is in electrical communication with the power terminal contact 14Vcc and with a power die contact 16Vcc. As shown in Figure 1D, a ground conductor 40Vss electrically connects the ground terminal 25 contact 14Vss, the ground die contact 16Vss and the first (lower) electrode 34. As shown in Figure 1E, a power conductor 42Vcc electrically connects the power terminal contact 14Vcc, the power die contact 16Vcc and the second (upper) electrode 36. In addition, as shown in Figure 1C, 30 generic conductors 44 electrically connect the remaining terminal contacts 14 to their corresponding die contacts 16 on the die 12.

Referring to Figure 2, a MCM package 50 that includes semiconductor components 10P-1, 10P-2 and 10P-3 constructed

in accordance with the invention is illustrated. The MCM package 50 can be configured as a system in a package (SIP) adapted to perform a desired function such as micro processing. Each semiconductor component 10P-1, 10P-2, 10P-3 5 includes an on board capacitors 32 constructed substantially as previously described for semiconductor component 10P (Figure 1A). However, the components 10P-1, 10P-2, 10P-3 can be configured to perform different electrical functions in the MCM package 50. For example, with the MCM package 50 10 configured as a micro controller, component 10P-1 can include an SRAM die, component 10P-2 can include a microprocessor die, and component 10P-3 can include a flash memory die.

The on board capacitors 32 contained on the components 10P-1, 10P-2, 10P-3 improve the performance of the MCM 15 package 50 by filtering transient voltages, spurious signals and power supply noise. In addition, the on board capacitors 32 are located close to the integrated circuits 24 (Figure 1D) on the components 10P-1, 10P-2, 10P-3 such that the function of the capacitors 32 is improved. Specifically, 20 fewer transient voltages and spurious signals are produced in the electrical paths between the capacitors 32, and the integrated circuits 24 than with prior art external capacitors.

The MCM package 50 also includes a substrate 52 wherein 25 the components 10P-1, 10P-2, 10P-3 are mounted using flip chip technology. The substrate 52 includes electrodes and conductors which electrically connect the components 10P-1, 10P-2, 10P-3 in a required electrical configuration. The substrate 52 also includes external leads 54 in electrical 30 communication with the components 10P-1, 10P-2, 10P-3. The MCM package 50 also includes a package body 56 formed of a cured plastic or other suitable material, which encapsulates the substrate 52 and the components 10P-1, 10P-2, 10P-3.

Referring to Figures 3A-3C, a multi chip module 58 that includes several semiconductor components 10P constructed as previously described with on board capacitors 32 is illustrated. The multi chip module 58 can be configured as a system for performing a specific function such as memory storage. The multi chip module 58 includes a module substrate 60 having patterns of electrodes 64 for flip chip mounting the components 10P to the module substrate 60. As such, the terminal contacts 14 on the components 10P can be bonded to the electrodes 64 on the module substrate 60 using a suitable bonding process, such as solder reflow or thermode bonding. The electrodes 64 are in electrical communication with conductors 62 formed on the module substrate 60 in a required circuit pattern. In addition, the conductors 62 are in electrical communication with an edge connector 66 which provides a connection point from the outside to the multi chip module 58. The on board capacitors 32 contained on the components 10P improve the performance of the multi chip module 58 by filtering transient voltages, spurious signals and power supply noise, substantially as previously described.

Referring to Figures 4A-4F and 5A-5F, a method for fabricating the component 10P is illustrated. Initially, as shown in Figure 4A, the semiconductor die 12 is provided. For simplicity, only a portion of the die 12 is illustrated. Preferably, the die 12 is contained on a semiconductor wafer containing a plurality of identical dice, and the fabrication steps are performed on all of the dice on the wafer.

Following fabrication, the dice will be singulated into a plurality of separate components 10P. The die 12 includes integrated circuits 24 formed in a semiconducting substrate using techniques that are known in the art. The die 12 also includes internal conductors 22 in electrical communication with the integrated circuits 24. In addition, the die 12

includes the die contacts 16 in electrical communication with the integrated circuits 24. The die contacts 16 can comprise a thin film aluminum layer, or another electrically conductive material. In addition, the die contacts 16 can 5 have a conventional shape (e.g., square or rectangular), a conventional size (e.g., 25 to 200 $\mu$ m on a side), and can be arranged in a conventional configuration. As shown in Figure 5A, the die 12 includes a ground die contact 16Vss and a power die contact 16Vcc. The die 12 also includes the 10 passivation layer 18 which can comprise an electrically insulating material such as BPSG or SiO<sub>2</sub>. As shown in Figure 5A, the passivation layer 18 includes openings 68 aligned with the die contacts 16.

Initially as shown in Figure 4B, the first (lower) 15 electrode 34 and the ground conductor 40Vss, are formed on the passivation layer 18 in electrical communication with the ground die contact 16Vss. The first (lower) electrode 34 and the ground conductor 40Vss, can be formed using a deposition process such as CVD, PECVD, PVD, sputtering or evaporation, 20 followed by photopatterning and etching. Suitable materials include aluminum, chromium, titanium, nickel, iridium, copper, gold, tungsten, silver, platinum, palladium, tantalum, molybdenum or alloys of these metals, such as TiSi<sub>2</sub>.

25 Preferably, the first (lower) electrode 34 and the ground conductor 40Vss, are formed from a first redistribution layer RDL1. Specifically, the first (lower) electrode 34 and the ground conductor 40Vss comprise portions of the first redistribution layer RDL1. Redistribution 30 layers are typically used in semiconductor manufacture to "fan out" the signals from standard die contacts 16, to contacts of a dense area array, such as a ball grid array (BGA). In an ideal situation, the die 12 would be designed to have the die contacts 16 in a pattern that does not

require the redistribution layer RDL1 to be added. For example, a semiconductor manufacturer can design the die 12 and the die contacts 16 such that the die contacts 16 are already in a grid array, for attaching solder balls of a ball 5 grid array (BGA). However, as this ideal situation does not always exist, redistribution layers are widely used in semiconductor manufacture.

In addition to forming the first (lower) electrode 34 and the ground conductor 40Vss, the redistribution layer RDL1 10 can be used to form the conductors 44 (Figure 1C) for the remaining die contacts 16, and pads 70 (Figure 1C) on the conductors 44 for bonding the terminal contacts 14. As shown in Figure 5B, the first (lower) electrode 34 and the ground conductor 40Vss, are in electrical communication with the 15 ground die contact 16Vss. In addition, the ground conductor 40Vss includes a pad 70Vss for bonding the ground terminal contact 14Vss.

Next, as shown in Figure 4C, the dielectric layer 38 for the capacitor 32 can be formed on the first (lower) electrode 20 34. The dielectric layer 38 is sized to separate the first (lower) electrode 34 from the second (upper) electrode 36 by a precise distance (d). The value of the capacitance (C) of 25 the capacitor 32 is a function of the distance (d), the area (A) of the dielectric layer 38, and the dielectric constant or permittivity (E). These parameters can be related by the well known formula  $C=E A/d$ . Depending on the application, the value of C can be selected from micro farads ( $\mu F$ ) to pico farads (pF).

The dielectric layer 38 can comprise a thin film 30 dielectric material having a desired dielectric constant (E). Suitable dielectric materials include polymers, oxides, nitrides, ceramics or other high dielectric materials. For example, polyimide, tantalum pentoxide ( $Ta_2O_5$ ) and polyvinylidenefluoride (PVDF) are suitable dielectric

materials. Depending on the material a suitable process such as deposition through a nozzle, spatuling, screen printing, or stenciling can be used to form the dielectric layer 38. Also depending on the material, a curing step, such as 5 heating at a selected temperature for a selected time period, may also be required.

Next, as shown in Figure 4D, the second (upper) electrode 36 and the power conductor 42Vcc, are formed on the dielectric layer 38 in electrical communication with the 10 power die contact 16Vcc. The second (upper) electrode 36 and the power conductor 42Vcc, can be formed using a deposition process such as CVD, PECVD, PVD, sputtering or evaporation, followed by photopatterning and etching. Suitable materials include aluminum, chromium, titanium, nickel, iridium, 15 copper, gold, tungsten, silver, platinum, palladium, tantalum, molybdenum or alloys of these metals, such as  $TiSi_2$ .

Preferably, the second (upper) electrode 36 and the power conductor 42Vcc, are formed from a second 20 redistribution layer RDL2. Specifically, the second (upper) electrode 36 and the power conductor 42Vcc comprise portions of the second redistribution layer RDL2. As shown in Figure 5D, the second (upper) electrode 36 includes a pad 70Vcc for the power terminal contact 14Vcc.

25 Next, as shown in Figure 4E, the outer protective layer 28 can be formed over the face 21 of the die 12 to encapsulate the capacitor 32 and associated conductors 40VSS, 42Vcc. The outer protective layer 28 can comprise a deposited polymer, such as polyimide, a glass, such as BPSG, 30 or an oxide such as  $SiO_2$ . The outer protective layer 28 can also comprise a photoimageable material, such as photoimageable polyimide, that can be blanket deposited as a wet or dry film, exposed through a mask, developed, and then cured.

As shown in Figure 5E, the outer protective layer 28 includes the openings 26 for the terminal contacts 14 in a required pattern and with required diameters. The openings 26 align with the pads 70 for the terminal contacts 14. The 5 openings 26 can be formed using an etchant and a mask, such as a photoimageable resist mask. Alternately, if the outer protective layer 28 comprises a photoimageable material, the openings 26 can be formed by exposure and development. In the illustrative embodiment, the outer protective layer 28 10 also functions as a solder mask to prevent bridging of solder material between the terminal contacts 14 during fabrication of the component 10P, and during flip chip mounting of the component 10P.

Next, as shown in Figures 4F and 5F, the terminal 15 contacts 14, including the ground terminal contact 14Vss and the power terminal contact 14Vcc, can be formed in the openings 26 in electrical communication with the pads 70. Prior to forming terminal contacts 14, the under bump metallization layers 30 can be formed in the openings 26 and 20 bonded to the pads 70. The under bump metallization layers 70 can comprise a suitable metal, such as copper, nickel, gold, palladium and molybdenum, formed using a suitable deposition process, such as CVD.

The terminal contacts 14 can be formed of a metal, such 25 as a solder alloy. For example, the terminal contacts 14 can comprise a solder alloy, such as 95%Pb/5%Sn, 60%Pb/40%Sn, 63%In/37%Sn, or 62%Pb/36%Sn/2%Ag. Alternately, the terminal contacts 14 can comprise a conductive polymer such as an isotropic or anisotropic adhesive, or a relatively hard metal 30 such as nickel, copper, beryllium copper, alloys of nickel, alloys of copper, alloys of beryllium copper, nickel-cobalt-iron alloys and iron-nickel alloys.

The terminal contacts 14 can be formed using a reflow process, or by electrolytic deposition or electroless

deposition. Another method for forming the terminal contacts 14 is by bonding pre-fabricated balls to the under bump metallization layers 30. A ball bumper can also be employed to bond pre-fabricated balls. A suitable ball bumper is 5 manufactured by Pac Tech Packaging Technologies of Falkensee, Germany. The terminal contacts 14 can also be formed using a conventional wire bonder apparatus adapted to form a ball bond, and then to sever the attached wire.

In addition, the number of terminal contacts 14, the 10 diameter D (Figure 1A) of the terminal contacts 14, and a pitch P (Figure 1B) of the terminal contacts 14 can be selected as required. A representative diameter D can be from about 0.005-in (0.127 mm) to about 0.016-in (0.400 mm) or larger. A representative pitch P can be from about 0.004-15 in (0.100 mm) to about 0.039-in (1.0) mm or more.

Referring to Figures 6A-6B, a wafer component 10W constructed in accordance with the invention is illustrated. The wafer component 10W comprises a semiconductor wafer containing semiconductor dice 12W. As shown in Figure 6B, 20 each die 12W includes an array of terminal contacts 14W. In addition, each die 12W includes an on board capacitor 32W constructed substantially as previously described.

Referring to Figure 6C, an electronic assembly 76W constructed using the wafer component 10W is illustrated. 25 The electronic assembly 76W includes a circuit board 72W and the wafer component 10W flip chip mounted to the circuit board 72W. In addition, the terminal contacts 14W on the wafer component 10W are bonded to electrodes 74W on the circuit board 72W. The capacitors 32W on the wafer component 30 10W function to reduce transient voltages, spurious signals and power supply noise in signals transmitted to the integrated circuits contained on the dice 12W on the wafer component 10W. In addition, the capacitors 32W improve test

procedures performed on the wafer component 10W, particularly wafer level burn-in.

Thus the invention provides improved semiconductor components having on board capacitors, a method for 5 fabricating the components, and systems incorporating the components. While the invention has been described with reference to certain preferred embodiments, as will be apparent to those skilled in the art, certain changes and modifications can be made without departing from the scope of 10 the invention as defined by the following claims.